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Control Management System for Air Conditioner via Power Line Communication Modem - PLC

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Abstract*—With several technological initiatives developed with the PLC modem (Power Line Communication), among the most varied themes developed regarding the relationship from the characteristics of the electric distribution networks, the study in transmitting data through the electric network is to show that it is possible to transmit the data in a fast, reliable and safe way through the electric circuit well structured, thus adjusting the connections between the profit, the reduction of costs and the conservation of preventive maintenance, mainly in what concerns the reuse of electric network in already structured places. However, in addition to implementing control management, we have identified some reasons that have not made it possible on a large scale as an alternative for transmission with regard to interference and noise and how we pointed out solutions to this problem. Thus, we addressed technical characteristics between equipment, circuit structure, multiplexing, frequency, technical comparisons with other data transmission technologies and an overview of the market, evaluating and showing that this technology has the potential to enable the communication of data in low-voltage electricity networks to serve the specific school, meeting the requirements for protocol transfer, especially for monitoring applications, and rapid response. The explanations about definitions, advantages, disadvantages, requirements, the interfaces of the electrical system and other arguments, are portrayed in a didactic and simple way, in order to facilitate the understanding of this technology.*

Keywords: PLC, data transmission, cost, monitoring.

I. INTRODUCTION

The idealization of transmitting data via the power grid is exceptional and very promising. In a country like Brazil, where it is very expensive to pay for internet broadband, taking advantage of the electric network that reaches practically all the companies in the country as a means of transmitting information would be a huge advance at a very low cost when compared to other means of transmission. This research has as improvement of the digital technology for benefits and comfort to a school of education.

According to RUIZ (2017,) PLC consists of data communication by power transmission lines, which have unique and expressive attributes that can be applied in telecommunications projects. We will delve deeper into this technology by presenting a method of data transmission in a management system for an air conditioner in a school located in the southern central zone of Manaus, as well as its future use scenario perspective.

Thus we will implement a device of optimum performance, using the Power Line Communication - PLC modem, for the management of the operation of the air conditioners in the school CEMETRO, having control and efficiency also in maintenance.

II. THEORETICAL FRAMEWORK

Today in all networks, whether residential or industrial, they need a means of data transmission, the most handled is the cable, and some operate in wireless transmission. The use of the same usually offers high cost, long period of installation, and need of maintenance, making the transmission medium subject to several types of weather and electromagnetic interferences.

According to Ruiz (2017, p.22), the study and improvement of technologies to reverse this unfavorable scenario is fundamental. Among the various means of access, the Power Line Communication - PLC appears as one of the viable alternatives for solving such a problem.

The PLC technology can be used as an alternative in an environment such as the school without the utility of installing its own physical means for data transmission,

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considering a financially viable hypothesis. However, in addition to the financial aspect, other requirements such as reliability, signal quality, safety, transmission distance, signal delay, among other parameters, are required before the school.

The main advantage of this technology is the use of an existing electrical network structure in the school for data transmission, to reach the distributions of the electrical network where, alternatives for quick access, are not yet available or connected to a specific network. And the disadvantage is the noise, in which according to Jardim (2016, p.03) noise is strange and unwanted signals in a means of communication distorting the signals of information. Noise overflow can make it difficult for a network to operate or drastically reduce its transmission.

According to Mendes (2006, p.06) the electrical structuring in a certain place already in activity, does not require any new electrical installation, and the network does not add any cost to your electric bill, PLC is the cheapest method of connecting diverse devices in different sectors.

The PLC to be used in this control system is suitable for any application and has a maximum capacity of 5120 digital I/O distributed by power between circuit connections by the school. According to Santos (2016, pg.34), PLC modems can be connected up to 7 expansion servers to a single CPU server, with a maximum number of 80 I/O air conditioners. The PLC modems will automatically monitor the transmission quality through the data transmission error control system, which helps when needed. The purpose of this system is to develop, through the basic principles, an air conditioner management control system of a teaching school, improving the practical knowledge in control, climatization and automation systems.

III. METHODOLOGY

Research of an applied scientific nature in which it is dedicated to the generation of knowledge for the solution of specific problems, directed to the search for the truth for a given practical application in a particular situation. It can also be called plan proposition, because it seeks to present solutions to certain organizational issues according to Lakatos (2012, pg.261). In this research, will be presented a management system for air conditioner in the school of Metropolitan Teaching Center of Manaus - Cemetro.

3.1 FIED OF STUDY

Centro Metropolitano de Ensino LTDA - CEMETRO, was founded on May 10, 2000, and its school year began on February 12, 2001. Aware that it is through education that all barriers and obstacles that slow down the development of a community and a country are overcome, it was created with the Metropolitan Institute of Teaching LTDA - IME as its maintaining entity. It is a civil society of educational and cultural character, whose purpose is the human promotion in all its aspects. The main characteristics of the study area are presented in Table 1.

Table 1 - Built area, number of classrooms in the school and number of air conditioners

Placeofstudy - CEMETRO		
Builtarea 2099,23 m²	QtyRoom	Qty Air Conditioner
Administrative	13	17
Class	23	28
Auditorium	1	1
Computer Laboratory	1	2
Dance	1	1
Teachers	1	1
Total	40	50

Source: Owner, 2018

3.2 STUDY PROJECT

The project was developed from the characteristics of low-voltage energy networks, a prototype that offers a sufficient rate in the physical layer and thus demonstrate that this technology has the potential to transmit a data communication in the low-voltage electrical distribution to the air conditioning devices in the school sectors.

The system consists of a PLC modem in addition to a configuration software that will manage the entire electrical network connected to each air conditioner. It was designed in two stages, first with the study of the location, placing technical data and second with the construction of the PLC modem, being done in two phases, first by creating the PLC modem in an Automation 5.0 simulator program, second by executing the PLC modem in the electric circuit in the Proteus 8 simulator program. We made a catalog of the air conditioners by sector and BTU.

Performing a comparison of the installation of the devices at school, provided for in the standard NBR 16401-1, shown below in Table 2, in which it was verified the compatibility if it is correct with the physical characteristics of the environment. In this table are the specifications of how many BTUs are needed to install by area.

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Table 2 - Standard NBR 16401-1 installation of air conditioner by area

Área	BTUs	Área	BTUs
9 m²	7500	30 m²	24000
12 m²	9000	40 m²	30000
15 m²	12000	50 m²	36000
20 m²	18000	60 m²	48000
25 m²	22000	70 m²	58000

Source: ABNT NBR 16401-1,2008

The manager has as one of the objectives the thermal comfort, in the words of Schipitoski (2016, p.02) we call by "condition of spirit in which the individual expresses satisfaction in relation to the thermal environment". This state is obtained when an individual is in a condition of balance with the environment in which he works, which means that the system will manage the temperature of the device according to the physical characteristics of the environment, in a domain of strict variation, without there being a sensitive effort of the devices.

We paid attention to the exposure of the sectors to the sun and also remember that even the number of people and electronic devices present in large numbers or with inadequate power in the environment can interfere with the capacity of the air conditioner. We specify in Table 3 the quantities of air conditioners for each sector, and which BTUs installed in relation to the area.

Table 3 - Number of air conditioners per BTU in each area per sector

Sector	Área	Qtyofairconditioner	BTUs
Reception/Conviviality	161,15	3	22000
Secretariat	32,94	2	18000
			9000
Financial	25,38	2	18000
			9000
Collection / Financial Pres.	15,75	2	9000
			7500
Teachers' lounge	63,63	1	22000
PedagogicalCoordination	11,3	2	7500
Direction	30,55	1	12000
Computer Laboratory	46,69	2	12000
Library	41,92	1	18000
humanresources	19,78	1	12000
TechnicalCoordination/EJA	19,78	2	7500
			9000
Warehouse/Proofs	28,3	1	18000
Dance Room	29	1	18000
Auditorium	64,8	1	22000
Classroom	31	5	18000
Classroom	40	15	18000
Classroom	20,4	8	12000

Source: Owner, 2018

IV. ANALYSIS AND DISCUSSION OF RESULTS

The construction of the simulator was made up of two parts: the first by automation a control circuit implementation using the logic of electronic distribution; the second by proteus in the construction of the program that will provide the input variables for the modem and also receive the output variables of the devices. For Ruiz (2017, p.21) there is a regulation for the conditions of use of radio frequency in broadband systems through the electric network. It was defined that we will use the 1.705 kHz to 50 MHz band to use the project.

As well as the automation program as the proteus, procedures have been carried out to make the power line modem useful for sending and receiving serial data via supply lines. According to Costa (2016, p.05) will demonstrate a high immunity to persistence of electrical noise in the power line, verifying errors to not give corrupted data.

4.1 PLC MODEM CONTROL AND DATA TRANSMISSION MONITORING

The modem provides bi-directional communication over the network of any voltage up to 250V AC and for frequency 50hz or 60hz. According to Pereira (2010, p.06) half duplex communication means you can transmit or receive data at a time, but not both at the same time. After the program provides serial data to transmit on its RX-IN pin, it switches to transmit and transmit the data through the power line.

When the transmission process is complete, it returns to reception mode. Data transfer is indicated by the red LED. Modem data reception is indicated by a green LED that is on the Txout pin itself. According to Farias (2017, p.34) the modem data communication is transparent to the user data terminals and independent of the protocol. There is no adversity in the structuring of interface circuits. The PLC modem card is shown in Fig. 1.

Source: Owner, 2018

Fig.1 - Power Line Communication Modem (PLC)

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The equipment of the PLC modem was installed in the input of the power outlet, where the power outlet of the air conditioner device is connected, throughout the development of this project showed that the manager acted considerably the signal of the PLC system. For Ruiz (2017, p.41) the PLC modem has the function of performing data communication with the other modems, so that the demands for consumer data services are met. The PLC modems communicate with other networks or with each other only through the PLC manager system.

Transmission is being based on byte per base byte. After giving the modem a byte for transmission, it was necessary to wait at least 500 ms (milliseconds) before a new byte is given to the modem again since the modem waits for the AC network to cross zero to transfer a bit. For Farias (2017, p.63) the AC system 50Hz, the zero crossing of AC signals happens every 10 ms and the modem needs 50 zero crossings to transmit a byte with error checking data. This is why it takes 500 ms for one byte. This can be quite a lot in relation to slow speed for large data transfer, but the purpose of this modem is to transfer small data bytes so that it recognizes the sensor readings so that this speed will work when implemented.

4.2 APPLICATION DIAGRAM

The diagram shown in Fig. 2 shows the application of the PLC modem in blocks.

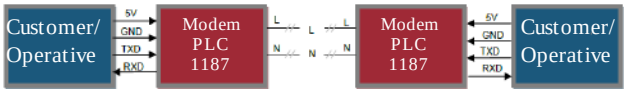
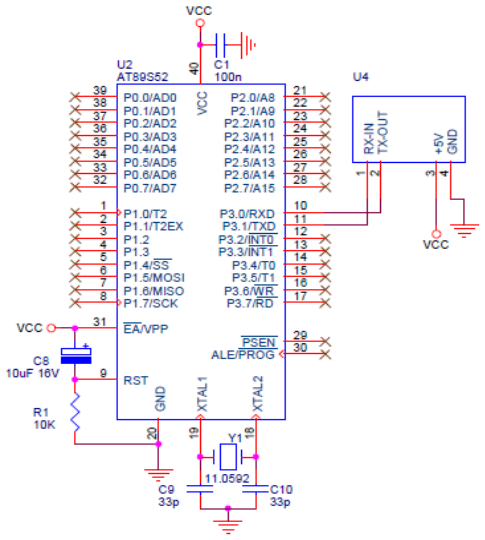


Fig.2 - AC Power Line

Details of the diagram interface shown in Fig. 2 refer to the PIN: RX-IN receives the 5V logic level input serial data input, in which it is connected to the TXD pin of the microcontroller. TX-OUT transmitted the 5V logic level serial data output, in which it is connected to the RXD pin of the microcontroller. +5V is the regulated 5V power input power source. GND is the power supply level that must be a common ground part of the microcontroller.

4.3 INTERFACES USED IN THE PLC MODEM

In the interface below shown in Fig. 3, it shows the interaction with the module directly with the pins of the microcontroller, since the module level is at 5V level. For Ruiz (2017, p.38) they can be used on any microcontroller, AVR, PIC or something similar. We just had to configure the microcontroller to communicate at 9600 baud rate. The TXD pin of the MCU will go to the RX-IN pin of the PLC modem, the RXD pin of the MCU will go to the TX-OUT pin of the PLC modem, ground power supply and + 5V between the PLC modem and the MCU must be connected. This document below has remote control application notes and little below the source code shown in Fig.4.



Source: Owner, 2018

Fig.3 - Simulation of the PLC interface in the automation program

O show how we will turn on/off the air conditioners through the PLC modem, we use an application that will be the control panel with ON and OFF switch. When activated the switch is pressed, the "A" character is transmitted, when the OFF switch is pressed, the "B" character is transmitted through the PLC modem. As shown in Fig. 4 a part of the source code to transmit the data and we have a basis for viewing the operation.

```
30    // -=-=- Program Loop -=-
31    while(1)
32    {
33          ch = mygetchar(); /
34          if(ch=='A') // if r
35          {
36            RELAY = 1;
37          }
38          if(ch=='B') // if r
39          {
40            RELAY = 0;
41          }
42       } // end while
43    }// end main
44
```

Fig.4 - Source code control panel with ON and OFF.

Na interfacecom ON e OFF com relay na Fig.5 estamos mostrando a simulação para os condicionadores de ar no painel de controle através de um relay para desligamento e ligamento através de agendamento de horário.

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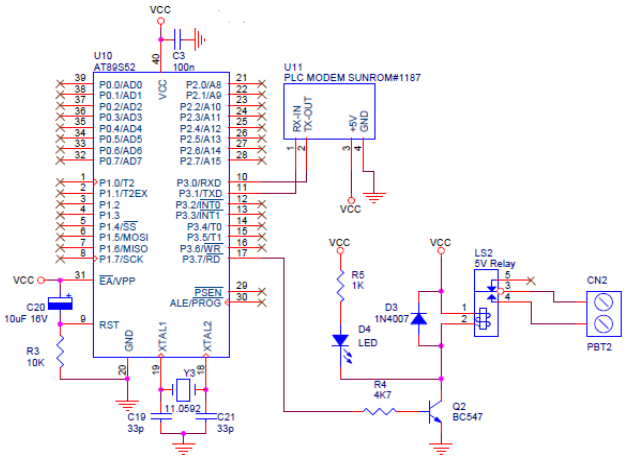

Source: Owner, 2019.

Fig.5 - Control panel simulation with ON and OF with relay.

V. CONCLUSION

This project, based on the data collected and the help of scientific research, was observed that it is possible to transmit data through the electricity grid, reliably, and can reuse the structure of the electricity grid, if it is in good condition of use and with the electrical circuits properly connected, thus the use can solve problems related to infrastructure and maintenance cost. Although there are problems with noise and weakness, with new technological developments in modeling and digital processing, we began to unveil practical applications in frequency and amplitude through the PLC, analyzing each channel present, thus providing the constant evolution of signal modulation techniques used.

The PLC modem can become a realizable alternative to the communication networks, not only reducing the cost, but also the installation time and the data communication time, for this, simulations were made closer to the real, isolating environment through controlled source, placing different number of inverters connected in the network, distance between transmitter/receiver modem, thus despite that the use of the frequency inverters affect the performance of PLC communication, causing losses of data packets. However, it showed that its modem is able to send and receive data in critical environments, at a low effective reference rate of 5 kbps, which allows concluding the feasibility of collecting information, which need to act in real time.

Therefore, the school has a new means for data transmission, called PLC modem, as a low-cost alternative, easy to install and that promises to meet the expectations of the school regarding the performance of air conditioners. The next steps to be followed for better monitoring of this project are the inclusion of monitoring functionality by the Zabbix program, monitor the power load and specify if any part of the air conditioner was affected.

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